

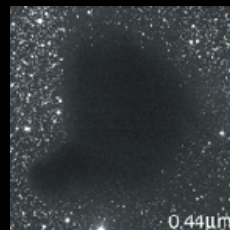
Some Important Questions

How to detect molecules
(observation)

Molecular formation
(explanation)

Chemical reactions
(prediction)

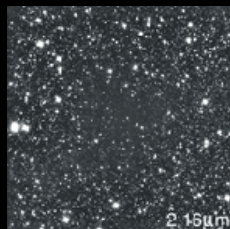
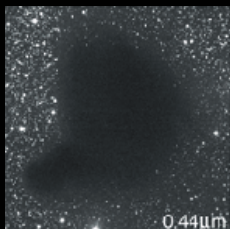
Consider ...



B68, a dark
nebula,
~ 0.5 LY across

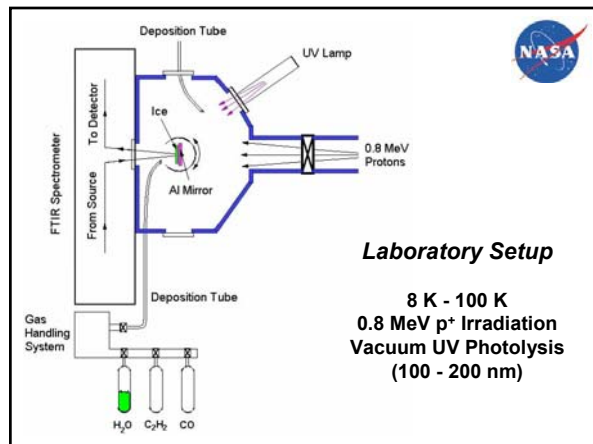
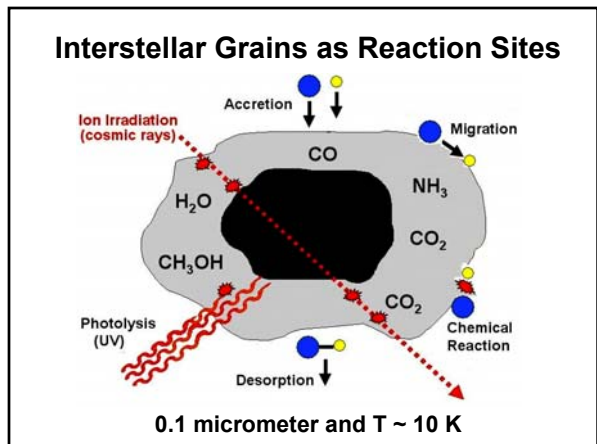
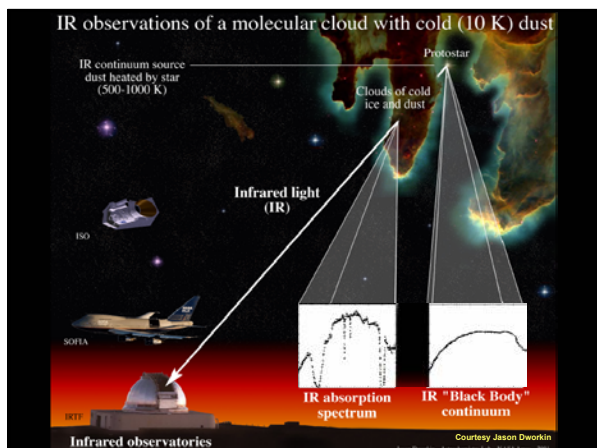
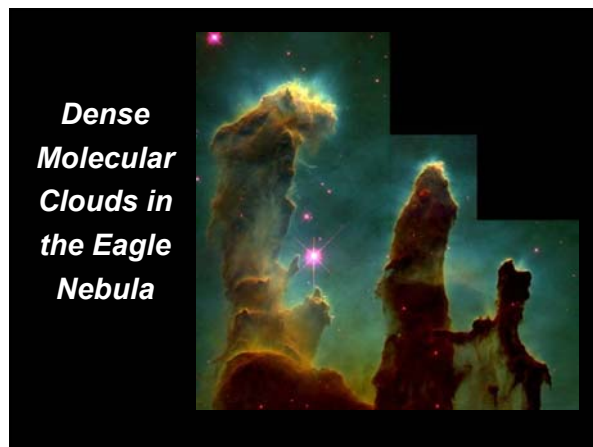
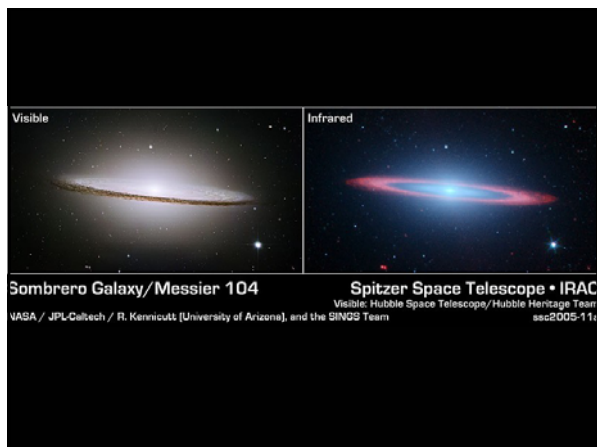
Long wavelengths
“cut” through the dust.

Consider ...



Long wavelengths
“cut” through the dust.





NASA Nerds in Action

Max Bernstein
(NASA HQ)

Scott Sandford
(Stardust mission)

Jason Dworkin
(Meteoriticist)

NASA Ames
Research
Center



Case History #1: Jupiter's Galilean Moons



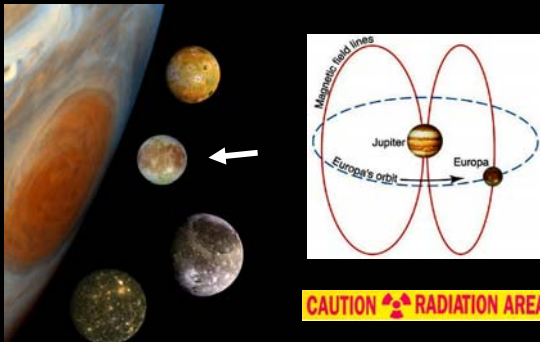
Launch - 1989

Arrive - 1995

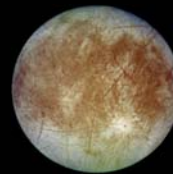
Mission Over - 2003

~ \$ 1.5 billion

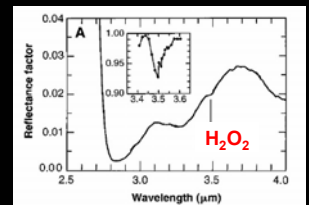
Chemistry and Jupiter's Satellites



Galileo Finds Hydrogen Peroxide (H₂O₂)



Europa



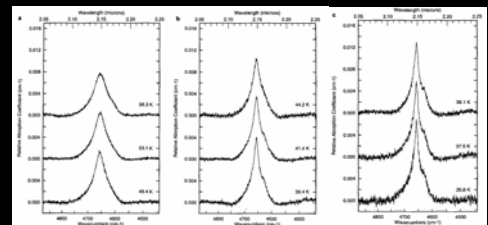
CAUTION RADIATION AREA

Case History #2: Transneptunian Objects

(Kuiper-Belt Objects, ~ 70,000 est.)



Measure Nitrogen Spectrum – Lab vs. Pluto



Pluto's Temperature is 38 - 42 K.

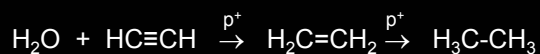
Case History #3: Molecules in Comets



Comet Hyakutake



Mumma et al., *Science*, 1996

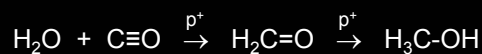


Moore & Hudson, *Icarus*, 1997 & 1998

Alcohols too!

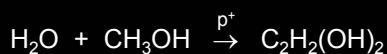


Comet Hyakutake
and many IS Objects
 CO , H_2CO , CH_3OH

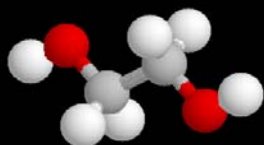


Hudson & Moore, *Icarus*, 1999

And Cometary Antifreeze: Ethylene Glycol



Hudson & Moore, *Icarus*, 2000

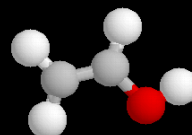


Discovered in Comet
Hale-Bopp in 2004



Discovered in the ISM in 2002

Case History #4: Interstellar Molecules



Vinyl Alcohol
 $\text{CH}_2\text{CH}(\text{OH})$

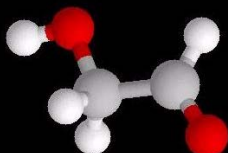
Predicted in 1997 & 1998
Discovered in the ISM in 2001

Erlenmeyer's Rule:
Vinyl alcohol converts
to acetaldehyde.



Emil Erlenmeyer
1825 – 1909
Berlin, Germany

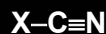
And the First ET Sugar: Glycolaldehyde, $\text{C}_2(\text{H}_2\text{O})_2$



Discovered in the interstellar medium in 2000

Astrobiology Connections

Simple Molecules Make
Complex Molecules.



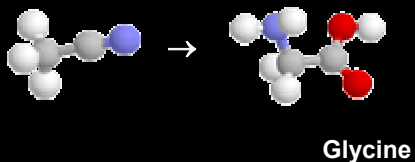
Nitriles are found in many places.

Nitriles are implicated in
prebiotic chemistry.



Amino Acid Synthesis

Nitriles → Amino Acids



Amino Acids in Space



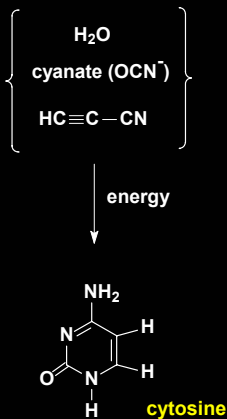
Dozens are found in carbonaceous meteorites.

Found in Stardust samples, collected from a comet.

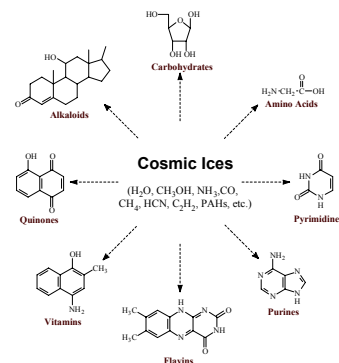
Predicted by both lab work and theory.

Nitriles make nucleobases (of DNA)

Found in meteorites too



ET Chemical Evolution



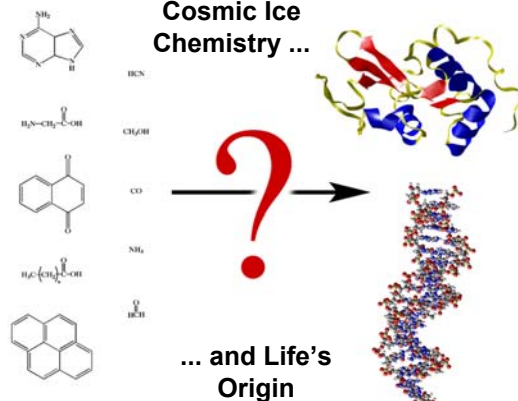
Courtesy Jason Dworkin

Cometary Bombardment and the Early's Earth Evolution



<http://www.astro.washington.edu/observatory/PastPresentations/>

Cosmic Ice Chemistry ...



Courtesy Jason Dworkin



Co-Workers and Students



***Thanks to friends
and colleagues whose
slides I stole!***

